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HISTORY OF LIFE ON EARTH

It is a fascinating experience to look-up at the sky on a clear night. Have you not wondered while looking up, when and how our planet earth came into existence? Or how life began and such diverse forms of life that we see around have evolved? These are some of the mysteries that scientists have tried to answer. In this lesson you shall learn how earth was formed, about theories explaining origin and evolution of life forms on this planet. The story will continue upto evolution of humans on earth.

OBJECTIVES

After completing this lesson, you will be able to:

- *describe the physical conditions of primitive earth;*
- *discuss the theory of origin of life (Oparin's theory) and relate it to the changing environment on earth;*
- *become aware of Darwin's major contributions;*
- *modify Darwin's thought to incorporate it in Neo-Darwinism;*
- *identify the levels of organic evolution;*
- *list the evolutionary events in the history of life;*
- *trace stages of human evolution through time.*

20.1 PHYSICAL CONDITIONS OF PRIMITIVE EARTH

The physical conditions on primitive earth were not congenial for life. The earth was extremely hot-a ball of hot gases.

20.1.1 Solar system and the formation of planet Earth

The universe around us is so enormous that it is difficult even to imagine its dimensions. In a far corner of the Milky Way Galaxy, (one of the billions of galaxies comprising the universe), sits our solar system, like a tiny sand particle on a vast sandy beach. Within this system, Earth, the planet on which we live, is one of the planets revolving around a medium-sized star we call the Sun.

ACTIVITY 20.1

Use any general knowledge book/geography book/science book/book on environment or use the internet to obtain a picture of earth and the other planets in the solar system. Highlight location of earth with a pen and observe it with respect to the sun.

The whole universe formed probably 12 to 14 billion years ago (one billion = 10^9 or 1,000,000,000) as a result of a 'Big Bang' and subsequent expansion. Our solar system came into existence 5-7 GY ago (GY = Giga Year). In its initial stages of formation (4.5 GY) earth was impacted by another planet that caused the spin (that gave us day and night) and tilt (that gave us seasons) of our planet and also led to the formation of moon. For nearly 700 million years (up to 3.8 GY ago), earth experienced frequent and catastrophic bombardment by meteorites of different sizes.

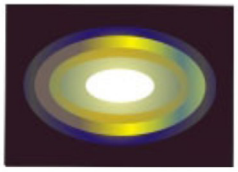
Gradually earth's crust solidified although volcanoes kept on spewing out harmful gases. These gases accumulated and combined to form **methane, ammonia and hydrogen cyanide**. These three gases, all lethal, along with minor gases like carbon dioxide and carbon monoxide, formed the atmosphere of the primitive earth. Thus, the prebiotic (before life arose) atmosphere was so unlike the present one. Note that there was no oxygen then, a gas so essential for nearly all living organisms.

ACTIVITY 20.2

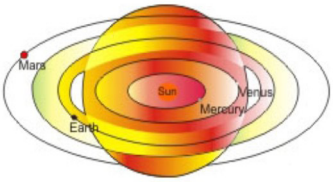
Select 5 friends, each one of you represent one of the 5 stages in the evolution of our planet- earth such as (i) our universe (ii) our galaxy- milky way, (iii) our solar system (iv) planet earth (v) India on this planet. You may dress yourselves in ways that would convey some important information/details about the "characteristics" that each one of you is going to represent. (You can take the help of internet or books or yours elders). Here some graphical representations are given below for your use. You may enlarge the graphics, select the appropriate one for the parts

each one of you is playing and display then on your dress. Practice your roles well in the correct sequence and when ready call your other friends and family members and present your show "story of 12-14 billion years."

Universe



Galaxy



Solar system

Earth

At the end you may even arrange for a quiz.

20.2. ORIGIN OF LIFE: WHEN, WHERE AND HOW DID LIFE BEGIN?

There is a general belief that life on earth must have originated, not before 4.0GY and no later than 3.5 GY ago. A more precise estimate is difficult to come up with, since the earliest life, did not leave any evidence in the form of fossils. Some fossils(remains of living beings that once existed on earth) claimed to be cyanobacteria (blue green algae) were found in Australia from rocks dated 3.5 GY. But cyanobacteria are fairly complex and advanced and therefore we may assume that life originated much earlier than 3.5 GY. So, for the present we accept that life originated nearly 3.8 GY ago.

One theory, proposed by the British biologist J. B. S. Haldane and the Russian scientist A. I. Oparin, suggested that life originated in the shallow seas where important organic compounds (such as amino acids), the building blocks of life, were present in high concentrations (forming a 'primordial soup'), thus providing the necessary ingredients for emergence of life. But where did these organic molecules come from? Haldane and Oparin suggested that in the reducing atmosphere (because of the absence of oxygen) of the primitive earth they could have formed from inorganic substances which were washed down with torrential rains as earth cooled and formed a 'primordial soup' in which life originated. Later Stanley Miller and Harold Urey provided experimental support for this hypothesis. Under laboratory conditions they successfully produced amino acids by passing an electric charge (simulating lightning) through a flask containing methane, ammonia and hydrogen in solution. (Fig. 20.1)

On the deep sea floor of the oceans there are sites which have vents or deep cracks through which extremely hot dissolved gases and minerals keep belching out like fountains from the earth's interior. A special group of **archebacteria** thrive near these vents as they are adapted to live at high temperatures exceeding 100°C (and hence their name, *hyperthermophiles*), and derive energy chemosynthetically from the hot gases. Evolutionarily, these microorganisms are very ancient (~ 3.5GY) and probably among the earliest living organisms on earth. These observations lend support to the more recent hypothesis that life evolved around such hydrothermal vents in the oceans.

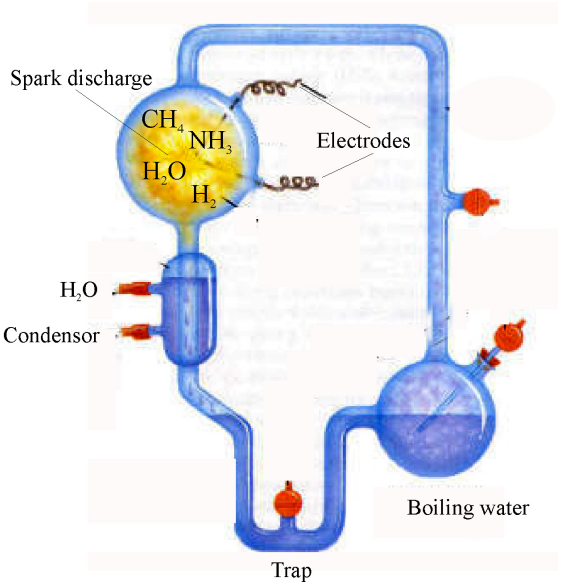


Fig 20.1 *Oparin and Haldane's experiment*

Belching: to enie contents violently

('~' means approximately)

GY = Gega Year

Regardless of where life had begun, how life emerged is still a mystery. Even if we assemble all the organic compounds essential for life we simply cannot produce from them a living organism capable of growing, reproducing and, storing and passing on a hereditary map to its offspring. How was it possible then that life suddenly emerged in a certain 'primordial soup' on the earth 3.8 GY ago? Did life arise from that soup of organic compounds in single step or through a few intermediate stages? Scientists are trying to understand the possible intermediate steps in the origin of life in the hope that one day in the near future they can produce in the laboratory a living form from basic organic molecules.

20.2.1 Diversification of Life

Life on earth started in the form of simplest unicellular (prokaryotic) microorganisms. In course of time these organisms evolved to utilize solar energy through chemical process called *photosynthesis*. You may recall that oxygen is released during this process. It is through the photosynthetic activity of the earliest autotrophs that oxygen built up gradually in the earth's atmosphere making it possible for complex heterotrophic organisms to evolve. For a very long time (nearly 3 GY) after the origin of life, earth had no life forms other than prokaryotes (cells lacking nucleus) comprising different groups of bacteria. There were neither plants nor animals. Eukaryotes (cells with nucleus) probably appeared about a billion years ago, but life was mostly in the form of unicellular (single celled) organisms. Then suddenly, about 600 million years ago, in a geological period called Cambrian, there was a great, almost explosive, diversification of life into

multicellular organisms with a variety of body plans and life styles,of all those invertebrates and higher plant groups that you are familiar with. Biologists call this period the '*Cambrian explosion*'. (See box I)

BOX- I The geological time scale

ERA	PERIOD	EPOCH	AGE (Millions of years)	MAJOR EVENT
Cenozoic	Quaternary	Recent		Historic time
		Pleistocene	1.8-0.01	Ice ages; Humans appear
	Tertiary	Pliocene	5-1.8	Ape-like ancestors of humans
		Miocene	23-5	Continued radiation of mammals and angiosperms
		Oligocene	34-23	Origin of most mammalian orders
		Eocene	57-34	Angiosperm dominance and increase in mammalian diversity
		Paleocene	65-57	Major radiation of birds and mammals
Mesozoic	Cretaceous		144- 65	Flowering plants appear Dinosaurs extinct at the end
	Jurassic		208-144	Dinosaur dominance First birds
	Triassic		245-208	Gymnosperm dominance First dinosaurs and mammals
Paleozoic	Permian		286-245	Radiation of reptiles
	Carboniferous		360-286	Extensive vascular tree forests, origin of reptiles
	Devonian		408-360	First amphibians and insects
	Silurian		438-408	Colonization of land by plants
	Ordovician		505-438	First vertebrates (jawless fishes)
	Cambrian		544-505	Origin of most invertebrate phyla
Precambrian			700	Origin of animals
			1,500	Origin of Eukaryotes
			2,500	Oxygenbuild-up in atmosphere
			3,500	Origin of life
			4,500	Origin of Earth

Fossils, the remains of plants, animals and lower living beings provide evidence for the sequence in which different kinds of living organisms came to exist on earth.

When a fossil is collected, the age of the sedimentary rock in which it is found is determined and that age is generally taken as the time in earth's history when that particular animal lived. Paleontologists (Scientists who study fossils)are able to reconstruct the history of life on earth from the fossils collected in sedimentary rocks of different ages. They clearly show that species and higher taxonomic groups (like angiosperms, insects and birds) evolved gradually. (See Box I)

INTEXT QUESTIONS 20.1

1. When did the earth come into existence?

   _____

2. Why did life not exist on primitive earth?

   _____

3. What are fossils?

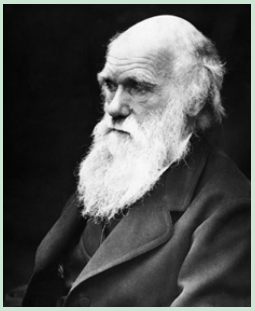
   _____

4. What is meant by Cambrain explosion?

   _____

5. From the geological time scale, find out the time in million years ago(mya) when:
   (i) dinosaurs became extinct _____
   (ii) human evolution began _____
   (iii) flowering plants became dominant on earth _____

BOX II
CHARLES DARWIN (1809- 1882)



Charles Darwin is, like Isaac Newton in Physics, a giant in Biology, whose theory of evolution revolutionized our understanding of life and its diversification on earth.

Darwin was born in Shrewsbury, England on February 9, 1809. He developed a passion for nature from early childhood, a trait he probably inherited from his grandfather Erasmus Darwin. His father wanted him to study medicine at Edinburgh but Darwin did not have the aptitude for it. He also did not pursue studies to become a cleric, his father's second choice. Darwin was offered the position of a naturalist on board the ship HMS Beagle which he accepted with excitement and enthusiasm.

The voyage on HMS Beagle was a major turning point in Darwin's life. During the five years (1831-1836) of its voyage he discovered rare fossils in Andes Mountains, collected fascinating animals and plants in Atlantic rain forests of Brazil and made observations on the geographic variation in the famous

Darwin's finches on Galapagos Islands. Darwin gained from all these experiences valuable insights and scientific support for the theory of evolution he was formulating.

Upon return to England, Darwin started accumulating more scientific material in support of his theory of evolution through a mechanism that he called **natural selection**. Darwin's famous book on "Origin of Species" was published in 1859.

Darwin died in 1882 at the age of 73. He was given state funeral and was buried in Westminster Abbey next to the grave of Isaac Newton.

Scientists around the world commemorated Darwin in 2009 by celebrating his birth bicentennial and the 150th anniversary of the publication of his famous book on the 'Origin of Species'.

20.3.1 Diversity of Life Resulted from Evolution

When we explore nature, we observe that

1. There is so much diversity of microbes, plants and animals in the biosphere of our planet.
2. Many animals and plants share common features. We humans are similar to rats, horses, elephants and tigers in possessing hair and mammary glands. Further, we share features like vertebral column with birds, snakes, frogs and fishes. In fact, all living organisms have so many characteristics in common, including DNA, the hereditary molecule.
3. There is so much variation even among individuals of the same species. You can easily notice that all your classmates are not alike; they differ from each other in features like height, facial expressions and skin pigmentation. Likewise, individuals in a school of fish, tomato plants in a vegetable garden, *Aedes* mosquitoes in a water tank, they all show variation in some feature or the other.

These three observations lead us to ask important questions. How and why did such huge diversity of life forms arise? Were the diverse life forms present from the beginning of earth's history or did they arise gradually over a period of time? Why do even remotely related organisms have so many features in common? Is it possible because they all came from a single ancestor? Why is there so much variation within any single species?

ACTIVITY 20.3

Collect the pictures of a plant, any animal and a human being from old news paper or magazines. Paste the pictures and note in the table shown below 3 features in which they are similar and three features in which they differ.

Living being	*Similarity*	*Difference*
	1.	1.
	2.	2.
	3.	3.

ACTIVITY 20.4

Note the eye colour, hair colour, earlobes of five of your friends and compare them with regard to the differences. This will give you an idea of variation which is necessary for origin and evolution of new species.

Name	*Eye colour*	*Hair colour*	*Ear lobes*
Rohan			
Mary			
Salim			

20.3.2 Darwin's Theory of Evolution- Salient Points

Darwin made important observations and drew inferences from them, which helped him in developing his theory of evolution.

The commonness of many features from anatomical to molecular is a clear indication that all organisms evolved from a common ancestor. Darwin concluded that living forms were not created but evolved by descent with modification from ancestral forms going back all the way to the earliest life more than 3.5 billion years ago.

Darwin's next question that needed an answer was-"What is the mechanism by which the origin of species by descent with modification could take place?"

Darwin suggested two very important points with regard to evolution.

(1) All living beings are related through ancestry.

(2) The mechanism which causes diversification of species from ancestors is '**Natural Selection**'.

Darwin made four important observations on his travel on the ship HMS Beagle. (See Box II)

1. All organisms tend to produce **more offspring** than can possibly survive. (e.g. only a few frog's eggs survive and become frogs).
2. In fact, population numbers tends to remain **fairly constant** over long periods of time.
3. Also, organisms in a species show **wide variation** in characteristics.
4. **Some** of the variations are **inherited**, and so **passed on to the next generation**.

From the above mentioned observations Darwin made these two following deductions:

1. Since most offspring do not survive, all organisms must be going through a **struggle for survival, being eaten, suffering from disease** and **competition. The struggle for existence** cause large number of individuals to die.
2. The ones who have characteristics that allow them **to survive and reproduce** better (i.e. possess most useful **adaptations** for surviving in the environment) **will pass on these characteristics** to their offspring. In other words, Nature selects the fittest individuals of the population. Natural Selection is the same as the famous phrase "**survival of the fittest**" coined by Herbert Spencer. Organisms with slightly less survival value will probably perish first, leaving the **fittest** to pass on their **genes** to the next generation.

To sum up, therefore, the best adapted individuals were selected by nature to survive and leave offspring for the next generation. Darwin called this mechanism **Natural Selection.**

In Darwin's time it could not be demonstrated that Natural Selection was the mechanism by which organisms evolved, but later scientists were able to find support for Darwin's theory in nature as well as in laboratory experiments.

ACTIVITY 20.5

Read carefully Box III and justify why many grand parents tell grandchildren that they slept comfortably in the open because there were no mosquitoes and wonder how mosquitoes have reappeared and it is impossible to sit outside after sun down.

20.3.3 Neo-Darwinism

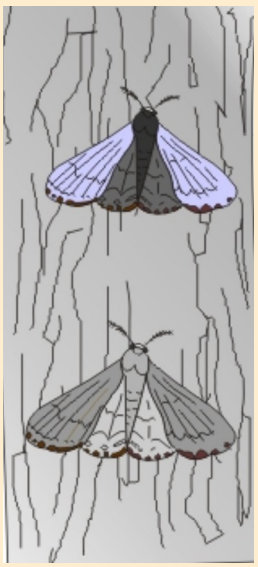
Although Darwin talked about heritable variation, he did not know exactly how heritable characters arose and were passed on from one generation to another. This is because Darwin was not aware of the principles of genetics developed by Mendel a few years before the publication of his book **'Origin of Species'**. Incorporation of Mendelian genetics into Darwinian theory later by evolutionary biologists led to the emergence of **Neo-Darwinism**. Further refinements in the light of advances in population genetics and other areas of biology led to the modern synthetic theory of evolution. It is to Darwin's credit that his basic theory of evolution by natural selection finds support even in the most recent developments in molecular biology. Read **Box III to** learn how natural selection acts on variation to produce new species. Also see figure 20.2

BOX-III
Natural Selection in Action

Although Darwin and many scientists of his time were convinced that natural selection is the right mechanism by which species evolve, they could not prove it experimentally or otherwise. It was felt that since any visible modification in a species evolves slowly over a long time, the effects of natural selection cannot be demonstrated easily. But, now we know that it can certainly be demonstrated, as you can see from the following examples:

1. Industrial melanism in peppered moth (*Biston betularia*) (see Fig.20.2)

***Fig: 20.2a** The* typica *(t) and* carbonaria *(c) forms of* Biston betularia *on the light-coloured trunk of a birch tree*



***20.2 b.** The* typica *(t) and* carbonaria *(c) forms of* Biston betularia *on the soot-darkened trunk of a birch tree*

Peppered moth is a common moth in England and it occurs in two varieties- a light-coloured variety called *typica* and a dark-coloured *carbonaria*. When these moths rest on the light-coloured trunks of trees, the *typica* moths get nicely camouflaged and cannot be spotted by birds that catch and eat them. But the *carbonaria* moths being dark against the light background of the bark stand out and are be easily located by the birds and captured. Because of this, the *carbonaria* moths suffered more predation and therefore always remained in very low numbers in the population. Then the industrial revolution in England in the mid 19th century brought in many coal-based industries and the resulting soot started depositing on the trunks of trees on the countryside. Soon after, scientists noticed that the numbers of *typica* moths started going down drastically while those of the *carbonaria* forms increased.

How did it happen? The soot deposits made the bark black and against the dark background, the *carbonaria* forms now had the advantage of camouflage whereas the *typica* moths became more and more vulnerable to bird predation. Consequently, the *carbonaria* form increased in numbers while *typica* numbers decreased. This is natural selection in action. In the industrialized England the dark *carbonaria* variety of the moth had the selective advantage because they escaped from bird predation more often and lived to leave more offspring for the next generation. Only the best adapted live and leave their genes in the next generation.

2. Evolution of insecticide-resistant mosquitoes

In our desperate efforts to control pest and disease-carrying vector insects, we have been spraying pesticides like DDT in large and larger quantities, but have not been able to eliminate them. When we spray a poisonous chemical on a population of mosquitoes, surely many of them die. But in any population there is variation for resistance and a few genetically resistant individuals survive the spraying. They breed and produce resistant offspring. In the next generation the proportion of pesticide-resistant individuals is higher. As spraying practice continues, the entire population becomes resistant in a few generations and thus a genetically distinct variety of mosquito has evolved on whom DDT has no effect.

INTEXT QUESTIONS 20.2

1. Who is Charles Darwin? Name his famous book on natural selection.

_____

2. Mention his two major contributions.

_____

3. What is the function of Natural Selection?

4. What is meant by Neo Darwinism?

5. Name the evolutionary mechanism that causes organisms to evolve.

20.4 LEVELS OF ORGANIC EVOLUTION

With progress in various fields of Biology, the theory of evolution by Natural Selection became more and more acceptable.

The unit of evolution, in the modern synthetic theory of evolution, is the **population**. It is the population which evolves and not the individual. **Variation** occurs at the genetic level through mutation and sexual reproduction in the "gene pool" of the population (gene pool means all the different genes in a population of individuals). Natural Selection causes **greater reproduction of the variant genes having adaptive advantage.**

Evolution at the level of the hereditary material or genes that is the gene pool of a population is termed **microevolution. Populations of a species differ due to microevolution**. **Macroevolution or adaptive radiation** is the evolution and diversification at the level of species and genera. eg Dinosaurs evolved as runners, fliers, swimmers due to macroevolution or adaptative radiation.

20.5 MAJOR EVENTS IN THE HISTORY OF LIFE

As we mentioned earlier, all the different life forms that we see on earth now evolved only gradually. Radiometric dating of geological (earths') strata and detailed study of the fossils found in them help us in reading important 'chapters' in the history of life on earth since its origin 4.5 billion years ago. Geologists have given names to different periods of this history (see Box I). You may recall that microscopic, unicellular prokaryotes were the exclusive life forms on earth for nearly three billion years. Dinosaurs ruled the earth for nearly 150 million years and became extinct 65 million years ago. Recall from sub-section 20.2.3, the appearance of eukaryotes and the Cambrian explosion. If you could have traveled 200 million years back in earth's history, you would have found neither birds nor flowering plants anywhere on earth! When did we humans arrive on this planet? Just 2 million years back (see the box on geological time scale)! If you consider the 24 hours geological clock with the

origin of life set at **midnight, we can say that humans have come on this planet just less than a minute ago**

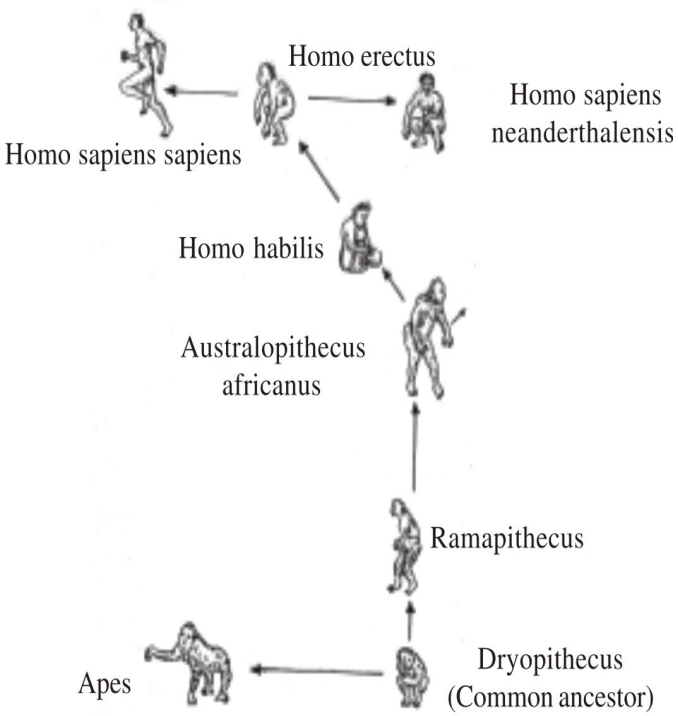
20.6 STAGES OF HUMAN EVOLUTION

When human evolution began, forests had dwindled because of glaciation (ice age). Much of the land surface was however, still covered by forests. The common ancestors of apes and humans had to come down from trees where they lived and walk on the ground using all four limbs. Recent molecular studies have shown that from common ancestors, evolution of apes (Chimpanzee, gorilla, gibbon and orangutan) and that of humans, diverged about 6 million years ago.

The trends of human evolution are towards (i) bipedal gait or walking on two legs and (ii) acquiring a large brain.

Fossil history reveals that human evolution began approximately 1.5 to 2 million years ago. *Australopithecus* is deemed to be the first human like ancestor. Fossils of an australopithecine named 'Lucy' has been found in African rock deposits. Thereafter, fossils of Homo *erectus* which walked on two legs, were unearthed from many parts of the world.

Next to evolve was *Neanderthal* man and *Cromagnon* man. They were both *Homo sapiens*. Modern man, *Homo sapiens sapiens meaning* the wise one evolved about 50,000 years ago. Since then, biological evolution of humans has perhaps not occurred. But vast steps of cultural evolution has made humans land on the moon!



Evolution of humans showing ancestor common to apes and humans

ACTIVITY 20.6

If you have enjoyed doing activity 2 where you and your friends enacted in the story of "12-14 billions years. You can arrange similar show with the heading "origin and evolution of *Homo sapiens sapiens.*

Some changes is required in graphic.

INTEXT QUESTIONS 20.3

1. When did human evolution begin?

   _____

2. Who is 'Lucy'?

   _____

3. Write the scientific name of Cro-magnon and Neanderthal man

   _____

4. With which group of animals do humans share their immediate ancestors.

   _____

5. Name the earliest ancestors of modern day humans.

   _____

WHAT YOU HAVE LEARNT

- We live on planet earth which is 4-5 billion years old.
- The earth along with other planets, their satellites, the sun, moon, the many galaxies form the universe.
- A solar system consists of a star in the middle with number of planets orbiting around it.
- Our planet earth is a part of its solar system and the sun is the star around which it revolves.
- Age of our earth is about 4.5 billion years.
- In the beginning, the earth was very hot but gradually the surface of earth cooled to form a hard rock.

- Life originated on earth in the distant past from chemical compounds through a series of chemical changes that occurred in water (chemosynthetic theory) proposed by AI Oparin and Haldane.
- Large molecules like proteins were formed which got together surrounded by membrane to produce the precursors of primitive cell. Thus unicellular organisms, came into being.
- It has, however, not been possible to create a cell in the lab.
- In the geological era called Cambrian, there was a great almost explosive diversification of multicellular organisms of different shapes, sizes and functions. This is known as Cambrian explosion.
- Evolution is formation of complex organisms through change from simple ancestral types over the course of geological time.
- Darwin's two major contributions were the idea of :
  (i) shared ancestry and
  (ii) natural selection as mechanism of evolution.
- According to Darwin, organisms produce more offspring than can survive because environmental resources are limited.
- In the organisms' struggle for existence, those with advantageous (variations) characters survive and reproduce to leave more offspring while the disadvantageous variants are eliminated. This is known as natural selection.
- With progress in genetics sources of variations were discovered and Darwin's original theory of natural selection was modified as Neo-Darwinism or modern synthetic theory.
- From the time of origin of earth (4.5 billion years ago) to the present, the entire period is divided into different eras: Precambrian, Paleozoic, Mesozoic, and Cenozoic.
- Major events of evolution were: Cambrian explosion and advent of mammals in the Cretaceous era.
- Human evolution began approximately 1.5 million years ago and main stages were *Australopithecus, Homo erectus* and *Homo sapiens.*

TERMINAL EXERCISES

1. What were the primitive conditions on earth. Tell your friend/cousin/ colleague. Then ask your friend to name the gas which was absent without which today no life can exist.
2. What are the main points of Oparins' theory of Origin of life? Make a five point quiz on it.
3. Mention Darwin's two major contributions to evolutionary ideas.

4. Write a note on NeoDarwinism.
5. List the five major events during geological time period beginning from origin of life. You may begin with origin of animals.
6. State major trends and stages of human evolution. Do you think humans are still evolving? Write five sentences to justify your response.
7. Earlier groups of animals became extinct due to natural happenings. Today, how is it that wild animals have become endangered and are heading towards extinction.
8. Write a ten sentences conversation between your father and yourself justifying the need for conservation of animals living in our forest.

ANSWER TO INTEXT QUESTIONS

20.1

1. 4.5 to 5 billion years ago.
2. Too hot and only certain gases present and reducing atmosphere.
3. Remains of organisms who lived in the past.
4. The time 600 millions years ago when sudden formation of different groups of invertebrates on the earth took place.
5. (i) 144-65 mya (ii) 1.5-2 million years ago (mya) (iii) 57-34 mya

20.2

1. Founder of theory of evolution.
2. (i) all organisms related through ancestry
   (ii) Mechanism of evolution is Natural Selection
3. Fittest individuals in a population survive and reproduce to leave the fit genes in the next generation.
4. Darwin's theory modified in the light of progress in genetics.
5. Natural Selection

20.3

1. 1.5 to 2 million years ago
2. *Australopithecus*
3. *Homo sapiens*
4. Apes
5. Australopithicus